SIMPLIFIED STRAPPED DOWN INERTIAL NAVIGATION UTILIZING BANG-BANG GYRO TORQUING

This invention is related to strapped down navigation systems. More particularly, this invention is related to a strapped down navigation system combining all axis, all attitude navigation.

BACKGROUND OF THE INVENTION

This invention is an improvement over U.S. patent application Ser. No. 407,121 now U.S. Pat. No. 3,924,824, Oct. 10, 1973, assigned to the same assignee as the present invention.

A strapped down navigation system derives its name because the inertial components comprising the gyros and accelerometers are "strapped down" or body mounted to the vehicle in which it is contained. In conventional strapped down inertial navigation systems, the gyro torquers are driven to force the spin axis (also referred to as the momentum vector) to coincide with the null axis. This practice necessitates a high up-date rate in the computer on the integration of the attitude equation. It also requires that the maximum torquer rate be able to compensate for high frequency small angle body motions. Basic to the disclosure of the application referred to above is a concept of a two step transformation from body fixed to inertially fixed coordinate frames. The first of these transformations is an attitude transformation based upon gyro pickoff outputs. The second transformation is based upon the angular rate of the gyro's momentum vector. This concept remains unchanged in the present invention and the improvements of the present invention include the above cross-track navigation concept and extends it to general all axis, all attitude navigation. Moreover, the present invention overcomes the restriction of the above device that the trajectory of the vehicle must be close to planar.

BRIEF DESCRIPTION OF THE INVENTION

The present invention provides a self contained strapped down inertial guidance system having two wide angle, two-degree-of-freedom gyros which are loosely captured and which furnish to a computing means attitude angle and angular rate signals along three axes. An accelerometer means also furnishes to the computing means signals representative of the acceleration along three linearly independent axes. A first transformation matrix in the computing means connected to the outputs of the gyros and accelerometers transforms the gyro and accelerometer signals from body coordinates to gyro coordinates. A second transformation matrix in the computing means connected to the output of the first matrix and to the gyros transforms the gyro coordinates into navigation coordinates. In order to perform navigational computations, computing means compute a transformation from gyro momentum vector (referenced to coordinate frame) to a navigational coordinate frame such as a locally vertical frame wherein the Z axis is always along the local vertical direction.

Accordingly, it is an object of this invention to provide an inertial navigation system in which a wide angle gyroscope is combined with constant level or bang-bang torquing to simplify computations in an all axis, all attitude, strapped down navigation system.

Another object of this invention is to provide an inertial navigation system in which the system is desensitized to higher frequency effects such as vehicle angular vibrations because the gyroscopes do not have tightly captured inertial elements which would necessarily follow all vehicle motion and vibrations.

These and other objects features and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawings wherein:

FIG. **1** is a simplified block diagram of a conventional strapped down inertial navigation system;

FIG. **2** is a block diagram of the improved strapped down inertial navigation system of the invention;

FIG. **3** is a graphical representation of the bang-bang gyro torquing technique of the invention;

FIG. **4** is a graphical representation of the gyro pick-off geometry of the invention; and

FIG. **5** is a block diagram of the mechanization of the locally level inertial navigation system of the invention.

Referring to FIG. **1**, there is shown a block diagram of a basic strapped down navigation system. The block diagram contains the attitude and acceleration sensors plus the computing means. Block **1** provides signals representing attitude angles and attitude rates to computing means **3**. Block **2** provides signals representing acceleration along the non-coplanar axes to computing means **3**. In the computing means the inertially sensed accelerations are transformed from a body fixed coordinate frame to an inertially fixed frame or other navigation frame, such as locally vertical frame.

Referring to FIG. **2**, block **20** contains two wide angle, two-degree-of-freedom gyros which have their cases rigidly mounted to the vehicle so that their momentum vectors are non-parallel. The gyros are torqued in such a manner that the long term torquing rates equal those of the vehicle so that all vehicle restrictions are removed. The spin axes of the gyros are adjusted so as to neither exceed a predetermined amount of angular freedom nor exceed the mechanical stops of the gyros. Angles θ, ψ and ϕ representing pitch, roll and yaw attitude signals respectively from the gyros are fed to a first transformation matrix **22** for coordinate computation. Acceleration signals along three non-coplanar axes are derived from block **21** and are also applied to matrix **22** where these inputs are transformed from body coordinates to gyro coordinates. The gyro coordinates output from matrix **22** is then applied with an input representing angular rate from the gyros **20** to the matrix **23** for computing the acceleration in navigation coordinates. The output signals representing acceleration in navigation coordinates from matrix **23** are applied to summing network **24.** Also fed to network **24** is a signal, g, representing gravitationalacceleration. Thus, the output of network **24** is a signal representing the acceleration in navigation coordinates corrected for gravitational acceleration. This signal is fed to a first integrating circuit **25** wherein the velocity (y) is computed and an output obtained. The same signal is also fed to a second integrating circuit **26** for computing position (x) as an output.

As can be noted from FIG. **2**, the gyros supply both a measure of attitude and angular rate. The fact that the gyros can be loosely captured thereby, permitting a controlled off null position, is an important feature of the mechanization. Moreover, this mechanization permits the mathematical development. The spin axis of the gyro is allowed to deviate from a null position with